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Goddard Space Flight Center
NASA
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ADVANCED COMMUNICATIONS AND NAVIGATION FOR MISSION SUCCESS
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Scott Schaire
Near Earth Network
CubeSat Communications

NEN CubeSat Support Agenda

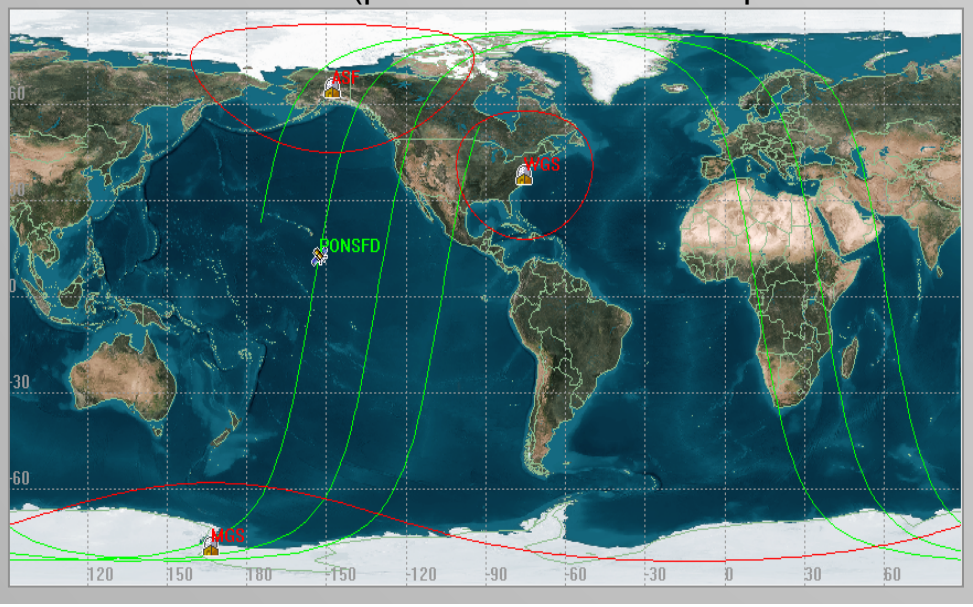
- Selected Common CubeSat Radios
- NEN Upcoming CubeSat Mission Support
- NASA Owned and Partnered Network Available to NEN
- NEN Baseline after Projected Expansions (FY20)
- Near Earth Network (NEN) Low Earth Orbit Small Satellite (Including CubeSats) Communication Support
- NEN Network Requested Time vs Number of Supportable CubeSats
- Exploration Mission (EM-1) and Future Exploration CubeSats
- NEN Ground System Performance Enhancements Required for Lunar/L1/L2
- Capitalizing on Commercial Service Providers (CSP)/Academic Partnerships
- NEN Evolution
- Conclusion

Selected Common CubeSat Radios

Freq.	Transceiver Name/Vendor	Size (cm)	Mass (g)	Flight Heritage	Max. Data Rate	Modulation/FEC	NASA Network Compatibility
UHF-band	L3 Cadet UHF Tx	6.9 x 6.9 x 1.3	215	DICE, MicroMAS, CeREs	2.6 Mbps	BPSK	None
	ISIS Transceiver (ITRX)	9.6 x 9.0 x 1.5	85	Delfi-n3Xt	1.2 Kbps Downlink/9.6 Kbps Uplink	Rx AFSK/Tx BPSK	None
S-band	Innoflight SCR-100	8.2 x 8.2 x 3.2	300	Sense NanoSat	4.5 Mbps	BPSK,QPSK,OQPSK GMSK,FM/PCM FEC: Conv. and R/S	NEN, SN, DSN
	Tethers Unlimited SWIFT-SLX	10 x10 x 3.5	380	None	15 Mbps	BPSK	NEN,SN,DSN
	L3 Cadet S-Band Tx (CXS-1000)	6.9 x 6.9 x 1.3	215	None	6 Mbps	BPSK, QPSK, SOQPSK, SGLS M/FSK	None
	Clyde Space S-Band TX (STX)	9.6 x 9.0 x 1.6	< 80	UKube-1			
	Nimitz Radio S-band Tx/UHF Rx	9 x 9.6 x 1.4	500	None	50 Kbps Downlink/1 Mbps Uplink	Uplink FSK, GFSK Downlink BPSK	None
	MHX-2420	8.9X5.3X1.8	75	RAX	230 Kbps Downlink/ 115 Kbps Uplink	FSK	Partially NEN
X-band	LASP/GSFC X-band Radio	9.8 x 9 x 2	500	None	12.5 Mbps Downlink/ 50 Kbps Uplink	BPSK/OQPSK R/S and Conv.	NEN
	Syrlinks/X-band Transmitter	9 x 9.6 x 2.4	225	None	5 Mbps	BPSK/OQPSK R/S and Conv.	NEN
	Marshall X-band Tx	10.8 X 10.8 X 7.6	<1000	FASTSat2	150 Mbps Downlink/50 Kbps Uplink	BPSK/OQPSK LDPC 7/8	NEN
	Tethers Unlimited SWIFT-XTS	8.6 x 4.5 (0.375U)	500	None	100 Mbps	{8,16A,32A}PSK	NEN,SN,DSN
	JPL /Iris Transponder	0.4U	400	INSPIRE	62.5 Kbps Downlink/1 Kbps Uplink	BPSK bit sync, CCSDS frame size	DSN, NEN (limited)
Ka-band	Canopus Systems/ Ames Ka-band Tx	18 x 10 x 8.5	820	None	125 Mbps	{Q,8,16A,32A}PSK, DVB-S2, CSSDS, LDPC Concatenated with BCH	NEN,SN,DSN
	Tethers Unlimited SWIFT-KTX	8.6 x 4.5 (0.375U)	500	None	100 Mbps	{Q,8,16A,32A}PSK, DVB-S2, CSSDS	NEN,SN,DSN

NEN Upcoming CubeSat Support

- **NEN will provide first time support to a CubeSat mission, CubeSat Proximity Operations Demonstration (CPOD), when it launches in 2016**
  - Supporting Station: WGS 11m, ASF 11m, MGS 10m
  - Level of Support: 2 contacts per day with a minimum duration of 5 minutes
  - Service Provided: S-Band Telemetry
  - Data Rates: 1 Mbps or 500 kbps
  - Service Duration: L+30 days to L+6 months (possible extension of up to L



Mission	Launch Date (No Earlier Than)
CPOD/PONSFD (A and B)	10/1/2016
SOCON	Mid 2017
iSAT	11/1/2017
CryoCube	3/1/2018
Lunar Ice Cube	7/1/2018 (EM-1)
BioSentinel	7/1/2018 (EM-1)
Burst Cube	2019
Propulsion Pathfinder (RASCAL)	TBD

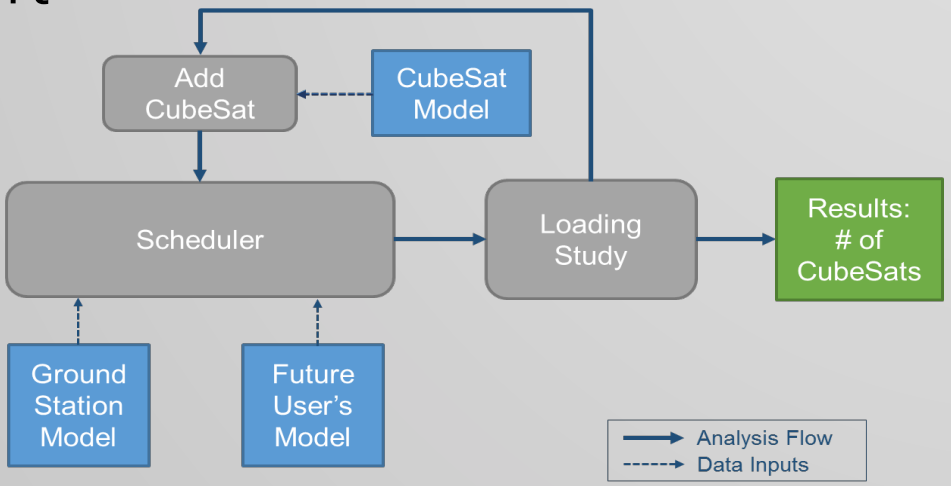
NASA Owned and Partnered Network Available to NEN

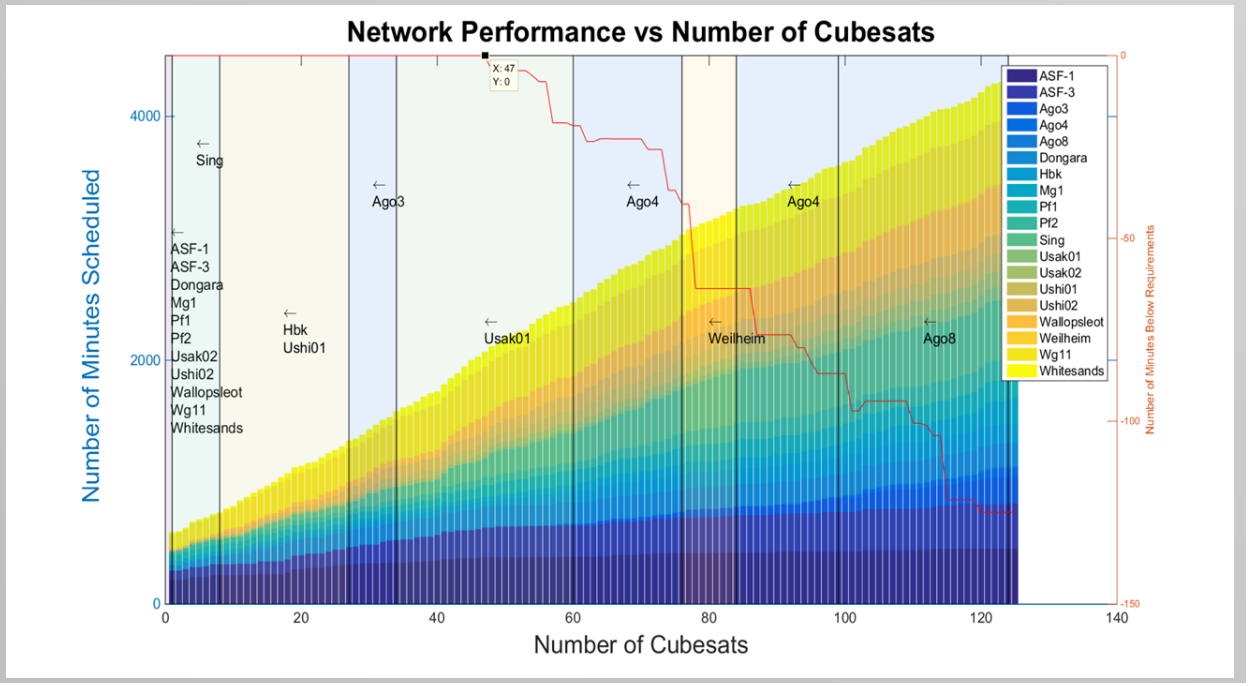
Station Name	Location	Assets and Service Types	NASA Owned or Contract
Wallops Ground Station	Wallops, VA	11.28 m X/S-band; 5 m S-band; VHF (2)	NASA
White Sands Complex	White Sands, NM	18 m Ka/S band; VHF (2)	NASA
McMurdo Ground Station	McMurdo Base, Antarctica	10 m X/S band	NASA
Alaska Satellite Facility	Fairbanks, AK	10 m, 11.28 m and 11 m X/S band	NASA
Launch Communication Systems	Ponce De Leon, FL and Kennedy Space Center, FL	6.1 m S-band (2)	NASA
NOAA Fairbanks Command and Data Acquisition Station	Gilmore Creek, AK	13 m X/S band (3)	Partnered
Kongsberg Satellite Services	Svalbard, Norway	11m X/S band; 13 m X/S Band (w)	Contract
	Singapore, Malaysia	11 m X/S band	Contract
	TrollSat, Antarctica	7.3 m X/S band	Contract
Swedish Space Corporation	Kiruna, Sweden	13 m X/S band (2)	Contract
Universal Space Network	North Pole, AK	11 m S-band; 5 m S-band, 11 m X/S band; 7.3 m X/S band	Contract
	Dongara, Australia	13 m S-band, 7.3 m X-band uplink	Contract
	South Point, HI	13 m S-Band (2), X-band uplink (3000W)	Contract
SSC/Santiago, Chile	Santiago, Chile	9 m S-band; 7 m S-band Transmit; 12 m S-band Receive	Contract
Council for Scientific and Industrial Research	Hartebeesthoek, South Africa	12 m S-band Receive; 6 m S-band Transmit	Contract
German Space Agency	Wilheim, Germany	15 m S-band	Contract

NEN Baseline after Projected Expansions (FY20)

Near Earth Network (NEN) Low Earth Orbit Small Satellite (Including CubeSats) Communication Support

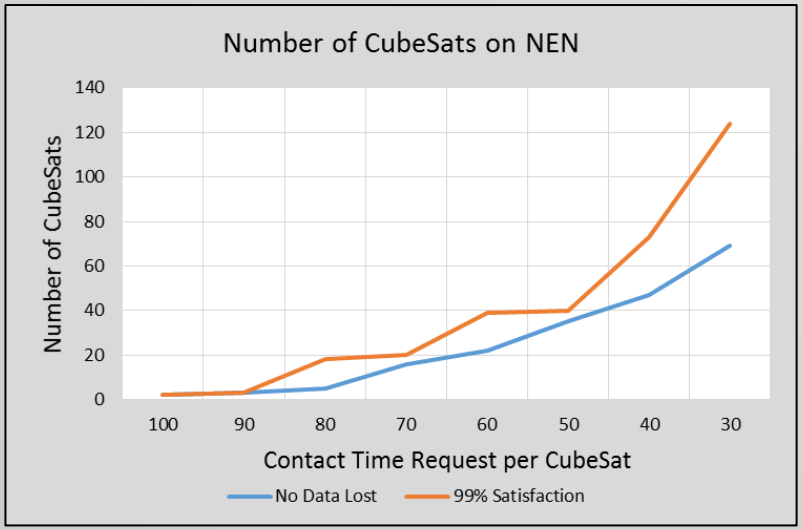
- **NEN performed a trade study to answer the question of how many CubeSats the network could support**
- **Study showed significant capacity if mission communication designs are coordinated with NEN**
- **Majority of NEN assets support polar orbiting missions**
- **Probable that interference between satellites will be the most limiting factor in the polar regions**
- **Growth and distribution in mid and lower latitude sites might be more effective at adding capacity and reducing latency**
- **Equatorial capacity could be improved with the addition of lower latitude stations to the NEN**





NEN Network Requested Time vs Number of Supportable CubeSats

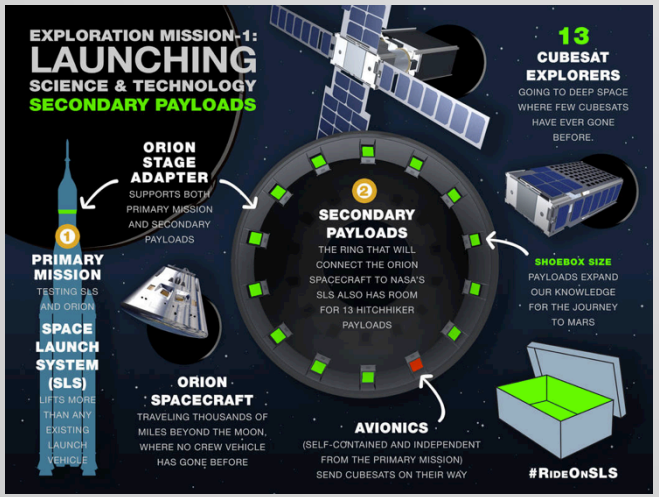
- **The total number of CubeSats is non-linearly related to the request of the individual CubeSat**
- **Network Scheduling Efficiency is highest when request for passes/day is lowest**
- **The NEN is exceptional at supporting large numbers of user's that request few passes/day**



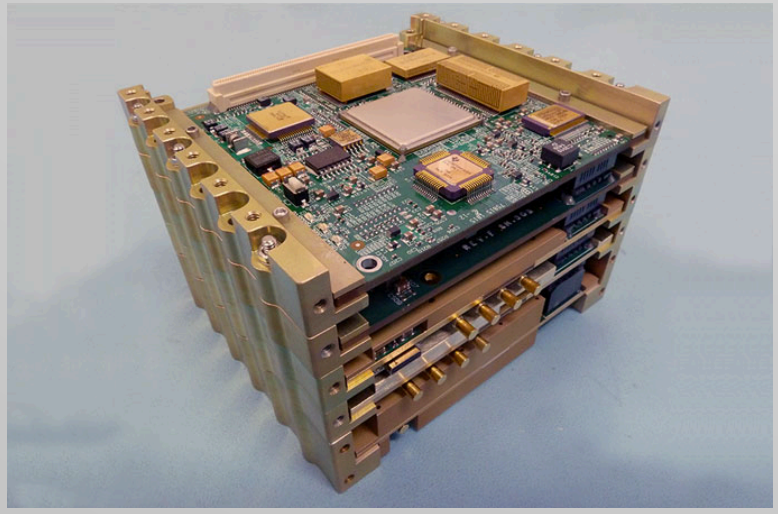
CubeSat Request (minutes)	Num CubeSats Allowable (w/o losing data)	Num CubeSats to 99% Network Satisfaction
100	2	2
90	3	3
80	5	18
70	16	20
60	22	39
50	35	40
40	47	73
30	69	124

Exploration Mission (EM-1) and Future Exploration CubeSats

- **NEN offers high gain large ground systems that are separated around the earth for full coverage of L1/L2 and Lunar missions**
- **Several of the EM-1 CubeSat missions propose to use the IRIS X-band radio with four X-band patch antennas, two for receive and two for transmit**
- **NEN Commercial Service Providers (CSP) have X-band uplink**
- **NASA NEN is considering increasing X-band uplink capability and with this upgrade EM1, EM2 and future CubeSat missions using X-band uplink radios (e.g. IRIS) can be supported beyond early orbit trajectory phase**
- **Adding X-band uplink to these ground systems would allow for CubeSats to also use the IRIS radio in near earth orbits**



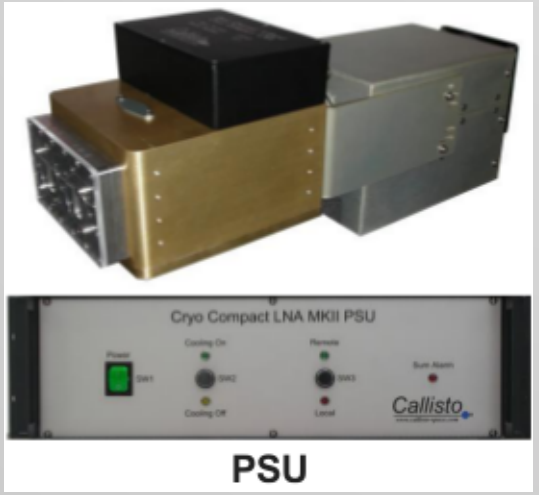
EM-1 Secondary Payloads



IRIS X-band Radio

NEN Ground System Performance Enhancements Required for Lunar/L1/L2

- **The gain of the earth station to the total system noise temperature, Gain/Temperature (G/T), is a crucial performance characteristic of the ground station antenna systems**
- **G/T measurements are basically the ratio of the antenna gain to the system noise temperature**
- **The most effective way of decreasing the system temperature is utilizing a low noise amplifier (LNA) to diminish the system temperature right after the antenna**
- **Currently NEN uses LNAs which have ~150 degrees Kelvin noise temperature**
- **However NEN can potentially consider upgrading the LNAs with less than 50 degrees Kelvin and ground systems can gain ~3-7+ dB in the ground system performance (i.e. that of ~18m)**



Example Cryogenic Low Noise Amplifier

Capitalizing on Commercial Service Providers (CSP)/Academic Partnerships

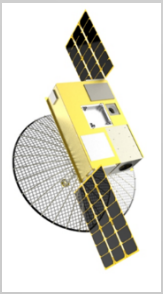
- **NEN today successfully manages commercial services**
- **CubeSats, because of their limited size and power, may require large ground stations (>11m) to support their data rate in Lunar, L1/L2 and LEO**
- **Potential commercial service and Academic Partnership large apertures may complement the existing worldwide fleet of 11m class X/S-band antennas and the 18m Ka/S-band antenna in White Sands**
- **Pass rate costs, required upgrades, existing capability and availability will be traded against potential benefits**
- **Morehead State University Space Science Center operates a 21-Meter Space Tracking Antenna that is capable of providing telemetry, tracking, and command (TT&C) services for a wide variety of space missions**

Morehead State University Space Science Center 21-M Ground Station, Morehead, KY

NEN Evolution

- **Enhance CubeSat radios and NEN receivers to achieve high data rates for CubeSat missions**
- **Maximize ground performance through cryogenic LNAs**
- **Assist missions moving to X, S and Ka-band**
- **Add/modify small apertures**
- **Add X-Band Uplink**
- **Capitalize on Commercial Service Providers (CSP)/Academic Partnerships including small apertures, large apertures and X-Band uplink**
- **Streamline mission planning and integration and test and scheduling activities**
- **Continue to engage with the CubeSat community**

NEN Wallops 11 Meter class antenna



NASA GSFC/Wallops LunarCube with deployable X-band antenna based on University of Colorado/Goddard X/S band CubeSat Radio and NEN

Conclusion

- After selection, no charge for pass supports for NASA missions using NASA-owned stations
  - Use of Commercial Service Providers/Partners of NEN is subject to budget appropriations
- Mission Planning, Integration and Test (MPI&T) services are negotiable, function of risk versus cost
- Questions – contact Scott Schaire, scott.h.schaire@nasa.gov, 757-824-1120, NASA Goddard Space Flight Center, Near Earth Network Wallops Manager
- Contributions from George Bussey, Serhat Altunc
- Providing communication services for the CubeSat community
- What are your requirements?